December 23, 1959

Headquarters Strategic Air Command
United States Air Force
Offutt Air Force Base, Nebraska

Attention: Major Daniel Anderson-DIMD

Dear Andy:

I am enclosing for your information a copy of a report which describes the basic design and operation of the Mark I Viewer. In general, this viewer allows a P.I. to view 70 mm. roll film positive transparencies of 100 l/mm. resolution at 12.2 X magnification without significant image quality degradation. Additionally, the viewer has a capability for mensuration with a 2% accuracy.

We shall be happy to discuss in more detail the specifications for the Mark I Viewer if you decide that this is advisable.

Sincerely,

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RLD:bm

Enclosure

70 MM INDIVIDUAL MENSURATION VIEWER - MARK I

I. General

The 70 mm Individual Mensuration Viewer will enable the operator to view any portion of a contact positive transparency of a negative at adequate magnification and to determine distances between two points in true feet on the ground. Its excellent optical system completely preserves the information contained on the positive transparency.

The entire viewing portion of the unit, including the optical system, the film transport and the associated electrical chassis, is contained in one cabinet. The computer section, including the analog units, the digital voltmeter read-out and associated equipment, is contained in a separate cabinet. An electrical cable connects both cabinets.

II. Optical System

Each frame contains oblique views in two directions, which are difficult to interpret when seen "on their side" or up-side down. For this reason, a complex mirror system was devised that projects the image horizon-up at all times. The design of this system required considerable ingenuity, since the usual image-rotating devices, such as a Dove prism, could not be used in this viewer. In addition, the 80-inch long optical path had to be folded to fit in a reasonable size cabinet. In the system finally evolved, a small pivoted mirror in front of the projection lens sends the beam to the left or right, and a pair of mirrors sends the beam upward to a large mirror, which in turn reflects the beam back and down to the largest of the mirrors, which directs the beam forward onto the screen.

A number of adjustments of the mirrors are necessary to make the image appear properly on the screen. Two of these adjustments can be changed by pressing a button, which causes the image to rotate 180° to put the apparent horizon toward the top of the screen. The mirrors are made of 1/2 and 1-inch plate glass, ground and polished to a flatness of 1/10 fringe over the effective lens aperture. They are front-surface aluminized and over-coated with silicon monoxide.

The optical system consists of the condenser assembly, the projection lens, the mirror assembly, and the screen. The condenser assembly, which is of conventional design, contains three plano-convex lenses, two heat filters, a 1000-watt projector bulb, and a spherical mirror behind the lamp. The unusually efficient heat-absorbing system uses an interference reflecting filter and a special absorbing filter.

The film must be held flat to within ± 0.003 inches or better in order to remain in accurate focus. In an initial attempt to accomplish this, the film was held under controlled tension between a pair of rollers. This technique was found to be unsatisfactory, however, so a specially devised glass vacuum platen was installed. This has the disadvantage that the very fine detail is lost when the vacuum is released to move the film; but it does not seem to impair the mensuration or scanning ability.

A number of high quality projection lenses were tested, and the Schneider Componon lens was found to have outstanding performance except for its field curvature. A field flattener was designed to compensate for the curvature and was tested with excellent results.

From many screen materials tested, two were found to be superior: a white plastic, if the unit is used in a darkened room; and a commercial material called Lenscreen for use in a semi-lighted room. This latter material has been selected for installation in the unit.

III. Film Transport and Controls

Mechanical and electrical interlocks prevent mensuration during the slew mode of operation. Interlocks have the additional function of preventing any film motion when the vacuum system is engaged.

The film transport will handle up to 500-foot reels. The transport unit is loaded through a pair of doors on each side of the cabinet.

The film drive unit and all optical components, including the screen, are mounted on a separate frame within the cabinet. This will ensure that the unit is stable and free from any vibration and stresses introduced by the building and operator. All the optical components are mounted so as to prevent mechanical stress.

The following description is keyed to the operation of each item on the console control panel with additional information as required. It is not intended as an engineering description of the equipment. The control panel is shown in Drawing J-30195. From left to right, the items are listed below.

A. Power Switch

This is a three-position toggle switch with the center position as "off". The lower position is the standby position for warming up the computer and other elements requiring a continuous operating condition for proper operation. There is a time delay relay in the circuit so that even

if the switch is thrown to the "on" position first, 1.5 minutes elapses prior to operation. The projection lamp is operational only when the switch is in the "on" position. Indicator lights at this switch show the condition of the viewer at all times.

B. Film Control

The film control switch is a joy-stick type control. Movement to the right or left causes the film to advance through the film path. The stick is centered for zero motion of the film and in this position, the manual controls may be used for final setting of the film. The speed of the film motion is controlled by the distance the stick is moved off vertical. In the extreme position, a switch is engaged and the film moves at maximum or slew speed of 200 feet per minute. The scanning speed is variable from 0.5 to 8.0 feet per minute.

C. Horizon

The horizon switch rotates a mirror in the optical system to control the position of the horizon. The horizon should always be at the top of the screen. However, with horizons at each end of the frame, image rotation is required. This is a two-position toggle switch operator controlled.

D. Frame Counter

This resettable counter is geared to the drive mechanism to indicate the frame number under study. If, due to differences in frame separation or any other cause, the number is in error when a certain frame is

reached, it can be corrected with the use of the add or subtract buttons; these are single-action buttons changing the number one digit for each depression.

E. Computer

The computer knob can be set for the various multipliers so that the digital voltmeter carries significant figures at all times. The nadir set position is used for setting the computer with the proper nadir off-set due to roll of the aircraft. The "off" position of the switch disengages a mechanical clutch to remove the computer from the drive system.

F. Altitude

This precision resistor is set for the flying height of the aircraft and is input to the computer as part of the positional computation.

G. Null

This button, when depressed, will establish a reference point for initiation of measurements. This will enable the viewer to measure small distances at any point in the format as well as distances from the nadir.

H. Manual Film Drive and Counters

This system is used in the final positioning of the film under measurement. With the computer control set at "off", the film is moved so that the film center is on the center cross-hair of the measuring system. The computer control is then set to "nadir set" and the number corresponding to the nadir off-set in millimeters is set into the counter. During this operation, the film remains fixed and the crank is connected only to the counter dial. This setting starts the computer in the proper geometrical position for further computations. When the computer control is set in one of the miltiplier positions, the counters are connected to the film drive, both manual and remote. The counters are so set that when

axis is crossed, a cover drops over one of the counters with a plus sign and the numbers appear on the other counter. When the number is minus, the flag covers the other counter and the numbers appear on the negative counter. The positive and negative directions of these counters are fixed and the operator must exercise judgement when changing orientation of the image to prevent measurement errors. The SOP for this action is being derived at this time and will be available for operator training on these viewers.

I. Focus

The focus control is a mechanical connection which moves the lens in or out for the operator to select his optimum focus.

J. Brilliance

The brilliance control is a spring-loaded three-position toggle switch. This switch activates a motor-driven Variac to increase or decrease the intensity of the projection lamp.

K. Vacuum

For detailed study of small areas, the film is held in a glass sandwich activated by a vacuum. A safety switch within the system prevents the operator from moving the film while the vacuum is operative. An indicator light indicates when the vacuum is applied.

IV. Computational System

A two-coordinate analog computer was designed for use with the 70-millimeter Individual Mensuration Viewer. The function to be solved is:

$$AB = H^2 (\tan \theta_B - \tan \theta_A)^2 + \left(\frac{H}{f}\right)^2 (X_B \sec \theta_B - X_A \sec \theta_A)^{\frac{1}{2}}$$

where X_B, X_A are the X-coordinates of the points B and A respectively and θ_B, θ_A are the Y-coordinates expressed as angles. The range of computation is:

$$-1.5 \text{ — } X \text{ — } 1.5$$

$$-60^\circ \text{ — } \theta \text{ — } 60^\circ.$$

The solutions to these two functions form the basis for the measurement capability of this viewer. Of the above functions, H is a constant for any frame and is set into the computer by the operator with a front panel control. The focal length is a constant for all exposures since the computer is designed for use with only one camera. The trig functions and x are the variables which must be measured and read into the computer for each point on the photo which is to be measured. Figure 1 is a functional block diagram of the computer as presently designed.

The computer input voltage is regulated and then used to excite the altitude (H) Variac. The setting of the altitude on this Variac, supplies a selected voltage to (1) the tangent pot, (2), the x pot, (3), the X_A memory pot, and (4) the Y_A memory pot. The tangent and secant pots are mechanically coupled to the film drive when the computer is engaged. The cursor drive is mechanically coupled to the x pot when the computer is engaged.

In operation, the selector switch is set in the "Nadir Set" position, the film is then moved so that the film center is on the cursor cross wire and the nadir off-set is set into the counter by the hand control. The computer is then engaged by setting the selector switch on one of the display ranges. The film and cursor are then moved until the initiation point of a measurement is under the cross wire. The "Null" button is depressed supplying power to the X and Y servos which in turn set the memory

potentiometers to retain the initial settings. When the "Null" button is released, the drive to the servos is removed and the pots remain in position and remember the X and Y positions of point A. The film drive and cursor are then positioned over the termination point of the measurement being considered. The X and Y signals from this point are compared with the remembered signals from the initiation point and the difference in X and Y is fed into the final summation circuit. The output of this circuit is the vector sum of a sine and cosine voltage and is displayed on the EDVM as a ground distance in feet.

The factor limiting the precision of this system is the resolution of the various control pots. If, for example, the largest distance to be measured is one million feet on the ground, and the memory pots have 10,000 windings, then each winding of the pot will equal 100 feet in distance. This minimum resolvable distance is controlled by the maximum measurement required and can be considered as a full scale precision. With this minimum resolution, it will be seen that on shorter distances, it will be impossible to obtain a 2% accuracy. However in distances wherein the resolution is not the limiting factor, then this computer should retain the 2% accuracy required over all of the format.

This computer does not consider factors involving aircraft pitch, earth curvature and image motion compensation. The roll of the aircraft is corrected in the location of the true nadir. An investigation of the various factors involved indicated that ignoring the earth curvature would introduce an error of less than 1.0% and that including the capability for correcting this factor within the computer would greatly increase its cost

and complexity. IMC is not corrected because it is possible to meet the basic 2% accuracy requirements without this correction. Again cost and complexity of the computer were secondary considerations.

As previously stated, this computer is designed for use with one camera design only. If a requirement exists for acceptance of other formats and focal lengths, then the basic concept of the computer will have to be modified. If the viewer is to be truly universal then it must accept photography from cameras of frame, strip or panoramic design. The computer or other mensurational device must accommodate the formats, focal length variations, and various tilt orientations as well as other considerations. There are two basic approaches to this accommodation problem: One is to design different units for "Plug-In" operation of the computer while the other is to use the viewer as a comparator with an electrical "ruler" for encoding x and y information which can then be used in another type computer. Each of these approaches has both advantages and disadvantages. In the computer presently designed for this viewer, the mechanical output of the film and cursor drives (x and y) are encoded directly into trigonometric functions which are usable only with this focal length and format. Therefore, the utilization of mensurational information from this viewer for other computer inputs would require mechanical and electrical re-design. However, if this multiple utilization is included in the operational concept of these viewers, then this re-design can be accomplished in a re-development effort. In this re-design, it may be desirable to provide linear electrical outputs and accomplish all trigonometric encoding within the multi-purpose computer which would be support equipment for the viewer.